DOCUMENT RESUME

ED 392 939 CE 071 074

TITLE	National Occupational Skill Standards. CADD: Computer Aided Drafting and Design.
INSTITUTION	National Coalition for Advanced Manufacturing, Washington, DC.
SPONS AGENCY	Department of Education, Washington, DC.
PUB DATE	94
NOTE	21p.
AVAILABLE FROM	NACFAM, 1331 Pennsylvania Ave., Suite 1410 N, Washington, DC 20004.
PUB TYPE	Guides - Non-Classroom Use (055)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Competence; Competency Based Education; *Computer Assisted Design; *Drafting; Employment Potential; Entry Workers; *Job Skills; *Job Training; Postsecondary Education; *Technical Education
IDENTIFIERS	*National Standards

ABSTRACT

This document identifies computer-aided drafting and design (CADD) skills that companies require of training programs and future employees. The information was developed by two committees of technically knowledgeable CADD users from across the United States and validated by several hundred other CADD users. The skills are aimed at a beginner CADD user and are written generically so as not to bias them toward any particular CADD software. The document lists technical skills in four categories: fundamental drafting skills, fundamental computer skills, basic CADD skills, and advanced CADD skills. In addition, a supplemental section lists the related academic skills in communication, math, and science; employability skills; recommended tools and equipment for CADD training; recommended hours of instruction; and recommended qualifications of a CADD instructor. (KC)

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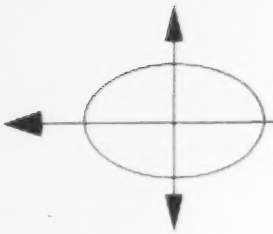

NACFAM

National Coalition for Advanced Manufacturing

National Occupational Skill Standards

CADD

Computer Aided Drafting and Design

U.S. DEPARTMENT OF EDUCATION
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THE FOLLOWING ORGANIZATIONS PARTICIPATED IN THIS PROJECT:

Aerospace Industries Association
AFL-CIO
Allen-Bradley Company
Alliance for Manufacturing Productivity
Altium
American Design Drafting Association
Association for Manufacturing Technology
Atlantic Resources Corporation
Augusta Technical Institute
Autodesk
BGSI
Cadkey
Career College Association
Chevron Overseas Petroleum
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Educational Leadership Consultants
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Trident Technical College
U.S. TRADOC
U.S. Department of Education
U.S. Department of Labor
Vocational Industrial Clubs of America
Vitro Corporation
Weber State University
Winterton and Associates

PREFACE

The information in this document was developed by NACFAM (formerly FIM) in 1994 under a grant from the U.S. Department of Education and with other significant inkind contributions from the CADD community. While the information was developed by two committees of technically knowledgable CADD users from across the U.S., it was validated by several hundred other CADD users as well. A partial list of the companies that participated on the committees is contained on the inside cover.

The skills and recommendations contained here reflect what companies need from training programs, students, and future employees. The skills are aimed at a beginner CADD user and they are purposely written in a generic fashion so as not to bias them toward any one CADD software.

To use this document effectively, a trainer should compare what he or she currently teaches students with the technical and academic skills listed in this document and make improvements. Trainers should adapt this information to fit the time limitations of their program and the level of students they are training. An employer could use this document to develop job descriptions, hiring criteria or promotional criteria.

Supplementary material is available for those concerned with assessing these skills. Committee members worked to determine evaluation criteria for each of the skills and this information is summarized in a measurability supplement which is available gratis. (This supplement is available gratis from the NACFAM Publications Department .) Work is underway to develop a national voluntary two-part CADD test based on the technical skills. The technical skills are scheduled for a review and update in 1996. A notice will be sent to all document purchasers when updates are available.

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THE TECHNICAL SKILLS

A. The skills contained in the Fundamental Drafting Skills Section are recommended basic knowledge, that must be demonstrated in a CADD environment.

B. CADD skills must be performed in accordance with appropriate industry standards (e.g. ANSI, ISO, building codes, individual company standards)

C. Refer to supplement for the related academic skills. The related academic skill(s) required to perform each technical skill listed in our document are contained in braces { } after each item. Skills prefaced by an M are math skills, by a C are communication skills, and by an S are science skills, In some instances, the related academic skill number referenced may include all items in its subsection (e.g., {M4} includes M4.1-M4.4).

D. These skills are listed in an order suitable for sequential learning.

1. FUNDAMENTAL DRAFTING SKILLS

1.1. DRAFTING SKILLS

1.1.1.	Use drawing media and related drafting materials (e.g., papers, vellum, mylar; plotter pens, toner cartridges)	{C11,C16}
1.1.2.	Use basic measurement systems (e.g., fractions, decimals, and metric measurements)	{M1, M7.1, M7.4, M13}
1.1.3.	Add correct annotation to drawing	{C1, C7}
1.1.4.	Identify line styles and weights	{M8.9}
1.1.5.	Prepare title blocks and other drafting formats	{C7, M8.9}
1.1.6.	Apply metric and/or dual dimensioning drawing standards	{S8}
1.1.7.	Identify and use appropriate standard symbols	{C10, C20, C21}
1.1.8.	Reproduction of originals using different methods (e.g., photocopy, plot, blueprint)	{M1}
1.1.9.	Create freehand technical sketches	{M4.2, M6, M8.9}

1.2. ORTHOGRAPHIC PROJECTIONS

1.2.1.	Identify, create, and place appropriate orthographic views	{M4.4, M8.9}
1.2.2.	Identify, create, and place appropriate auxiliary views	{M1, M4, M4.4, M6, M8, M8.9}
1.2.3.	Identify, create, and place appropriate section views	{M6, M8.9}

1.3. PICTORIAL DRAWINGS

1.3.1.	Identify and create axonometric drawings (e.g., isometric, dimetric, trimetric)	{M1, M 6, M8.9}
1.3.2.	Identify and create oblique drawings (e.g., cabinet, cavalier)	{M1, M6, M8.9}
1.3.3.	Identify perspective drawings (e.g., 1-point, 2-point, 3-point)	{M8.9}

1.4. DIMENSIONING

1.4.1.	Apply dimensioning rules correctly (e.g., avoid redundant dimensioning or dimensioning to hidden lines)	{S11}

1.4.2.	Use correct dimensioning line terminators (e.g., arrowheads, ticks, slashes)	{S2, S3, S8, S11}
1.4.3.	Dimension objects (e.g., lines, arcs, angles, circular)	{S2, S3, S8, S11}
1.4.4.	Dimension complex shapes (e.g., spheres, cylinders, tapers, pyramids)	{S2,S8,S11}
1.4.5.	Dimension features from a center line	{S2, S3, S8, S11}
1.4.6.	Dimension a theoretical point of intersection	{S2, S3, S8, S11}
1.4.7.	Use appropriate dual dimensioning standards	{S2, S8, S11}
1.4.8.	Use size and location dimension practices	{S3,S8,S11}
1.4.9.	Use various dimensioning styles (e.g., Cartesian, polar, ordinate, datum)	{S3,S8,S11}
1.4.10.	Place tolerance dimensioning and Geometric Dimensioning and Tolerancing (GD&T) on drawings when appropriate	{M1,S2,S3,S8}
2. FUNDAMENTAL COMPUTER SKILLS		
2.1. HARDWARE		
2.1.1.	Demonstrate proper care of equipment	{C10, C11, C17, S11}
2.1.2.	Operate and adjust input devices (e.g., mouse, keyboard, digitizer)	{C10, C11, C17, S11}
2.1.3.	Operate and adjust output devices (e.g., printers, plotters)	{C10, C11, C17, S11}
2.1.4.	Correct handling and operation of storage media	{C10, C11, C17, S11}
2.1.5.	Start and shut down work station	{C10, C11, C17, S11}
2.1.6.	Adjust monitor controls for maximum comfort and usability	{C10, C11, C17, S11}
2.1.7.	Recognize availability of information services (e.g., electronic mail, bulletin boards)	{C1, C2, C10, C11, S11}
2.2. PHYSICAL AND SAFETY NEEDS		
2.2.1.	Demonstrate an understanding of ergonomic considerations (e.g., keyboard position, screen position, lighting)	{C10, C11, C17, S11}
2.2.2.	Demonstrate personal safety (e.g., electrical and mechanical hazards)	{C10, C11, C17, S11}

2.3	**OPERATING SYSTEMS**	
2.3.1.	Start and exit a software program as required	{C10, C11, C17, S11}
2.3.2.	Demonstrate proper file management techniques (e.g., copying, deleting)	{C10, C11, C17, S11}
2.3.3.	Format floppy disk	{C10, C11, C17, S11}
2.3.4.	Identify, create, and use directory structure and change directory paths	{C10, C11, C17, S11}
2.3.5.	Demonstrate proper file maintenance and backup procedures	{C10, C11, C17, S11}
2.3.6.	Translate, import, and export data files between formats (e.g., IGES, DXF)	{C10, C11, C17, S11}
2.3.7.	Use on-line help	{C10, C11, C17, S11}
2.3.8.	Save drawings to storage devices	{S11}

3. BASIC CADD SKILLS

The following skills must be performed in 2D and/or 3D as appropriate.

3.1.	**CREATE**	
3.1.1.	Create new drawing	{M1, M2, M4, M6, M7, M8.9, S11}
3.1.2.	Perform drawing set up	{C10, C11, C17, M1, M2, M4, M6, M7, M8.9, S3, S8, S11}
3.1.3.	Construct geometric figures (e.g., lines, splines, circles, and arcs)	{M1, M4, M6, M7, M8.9, S11}
3.1.4.	Create text using appropriate style and size to annotate drawings	{M1, S8, S11}
3.1.5.	Use and control accuracy enhancement tools (e.g., entity positioning methods such as snap and XYZ)	{S3, S8, S11}
3.1.6.	Identify, create, store, and use appropriate symbols/libraries	{C10, C20, C21, M1, M4, M6, M7, M7.1, M8.9, S2, S3, S8, S11}
3.1.7.	Create wireframe/solid models	{M1, M4, M6, M7.1, M7.4, M8.9, M12, S2, S3, S8, S11}
3.1.8.	Create objects using primitives	{S2, S3, S8, S11}
3.1.9.	Create 2-D geometry from 3-D models	{M8}

3.1.10.	Revolve a profile to create a 3-D object	{M1, M8.9, S3, S8, S11}
3.1.11.	Create 3-D wireframe models from 2-D geometry	{M8 }
3.2. EDIT		
3.2.1.	Utilize geometry editing commands (e.g., trimming, extending, scaling)	{M1, M8.9, S2, S3, S8, S11}
3.2.2.	Utilize non-geometric editing commands (e.g., text, drawing format)	{M1, M8.9, S2, S8, S11}
3.3. MANIPULATE		
3.3.1.	Control coordinates and display scale	{M8.9, M9, M10, M11, S2, S3, S8, S11}
3.3.2.	Control entity properties (e.g., color, line type)	{S3, S8, S11}
3.3.3.	Use viewing commands (e.g., dynamic rotation, zooming, panning)	{M8,.9, S11}
3.3.4.	Use display commands (e.g., hidden line removal, shading)	{M8.9, S11}
3.3.5.	Use standard parts and/or symbol libraries	{C8, C10, C11, M1, M8.9, S11}
3.3.6.	Plot drawings on media using correct layout and scale	{M1, M8.9, S2, S3, S8, S11}
3.3.7.	Use layering techniques	{S11}
3.3.8.	Use grouping techniques	{S11}
3.3.9.	Minimize file size	{S11}
3.4. ANALYZE		
3.4.1.	Use query commands to interrogate database (e.g entity characteristics, distance, area, status)	{C11, M5.1, M5.2, M5.3, M5.4, M5.5, M7.1, S8, S11}
3.5. DIMENSIONING		
3.5.1.	Use associative dimensioning correctly	{S11}

4. ADVANCED CADD SKILLS

4.1.	**CREATE**	
4.1.1.	Create wireframe and/or solid models	{S2, S3, S8, S11}
4.1.2.	Create non-analytic surfaces using appropriate modeling (e.g., non-analytic: NURBS, B-spline, Gordon, Bezier, Coons)	{S2, S3, S8, S11}
4.1.3.	Create analytic surfaces using appropriate modeling with planes and analytic curves (e.g., conic, cylinder, revolution, ruled)	{S2, S3, S8, S11}
4.1.4.	Create offset surfaces	{S2, S3, S8, S11}
4.1.5.	Find intersection of two surfaces	{S2, S3, S8, S11}
4.1.6.	Create joined surfaces	{M8.9, S2, S3, S8,S11}
4.1.7.	Create a fillet or blend between two surfaces	{S2, S3, S8, S11}
4.1.8.	Create feature based geometry (e.g., holes, slots, rounds)	{M8.9}
4.1.9.	Create cut sections	{M1, M8.9, S2, S3, S8, S11}
4.1.10.	Construct and label exploded assembly drawings	{C1, C7, M1, M6, M8.9}
4.1.11.	Perform Boolean operations (e.g., union, subtraction, intersection)	{S2, S3, S8, S11}
4.2.	**EDIT**	
4.2.1.	Trim surface	{M1, M8.9, S3, S8. S11}
4.2.2.	Manipulate surface normals	{M1, M8.9, S3, S8. S11}
4.2.3.	Extend surface	{M1, M8.9, S3, S8, S11}
4.2.4.	Edit control points (e.g., surfaces, Bezier)	{M1, M8.7, S3, S8, S11}
4.2.5.	Modify geometry via Boolean operations	{S2, S3, S8, S11}
4.2.6.	Edit primitives (e.g., moving, copying, resizing)	{S2, S3, S8, S11}

4.3	**MANIPULATE**	
4.3.1.	Perform axis view clipping	{M8.9, S2, S3, S8, S11}
4.3.2.	Extract wireframe data from surface/solid geometry	{S11}
4.3.3.	Shade/render object (e.g., reflectivity, opacity)	{M1, M8.9, S2, S3, S5, S6, S7, S8, SD11}
4.4.	**ANALYZE**	
4.4.1.	Extract geometric data	{C11, S3, S8, S11}
4.4.2.	Extract attribute data	{S8, S11}
4.4.3.	Identify gaps in non-intersecting surfaces	{M4.1, M4.3, M4.4, M5, S11}
4.4.4.	Obtain surface properties (e.g., area, perimeter, bounded volume)	{M4.3, M4.4, M5, S2, S3, S8, S10, S11}
4.4.5.	Obtain mass properties data (e.g., moments of inertia, centroids)	{S2, S3, S8, S9, S11}
4.5.	**CADD PRODUCTIVITY AND WORK HABITS**	
4.5.1.	Perform customization to improve productivity (e.g., customize menus, function keys, script files, macros)	{C8, C10, C11, S11}
4.5.2.	Manipulate associated non-graphical data	{C8, C10, C11, S11}
4.5.3.	Use template and library files to establish drawing standard presets	{C8, C10, C11, S11}
4.5.4.	Develop geometry using parametric programs	{S2, S3, S8, S11}

Part II

SUPPLEMENTS

Related Academic Skills
- Communication {C} Skills
- Math {M} Skills
- Science {S} Skills

Employability Skills

Recommended Tools And Equipment for CADD Training

Recommended Hours Of Instruction

Recommended Qualifications Of a CADD Instructor

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THE ACADEMIC & EMPLOYABILITY SKILLS

A. The recommended list of related academic skills contains academic knowledge necessary for a CADD user to be proficient. With the acquisition of these skills, it is assumed that the user has writing capabilities, a technical vocabulary, can use the algebraic order of operations to solve problems and generate conclusions, and can use computers to process information for mathematical applications and problem solving.

B. The principal source of the related academic skills section is The Basic Taxonomy of Skills by Lester Snyder.

C. The list of employability skills is considered desirable for a CADD user in order to become a better worker.

D. The principal source of the employability skills section is the document produced by the SCANS Commission (Secretary's Commission on Achieving Necessary Skills).

E. The recommendations concerning tools and equipment, hours of instruction, and CADD instructor qualifications were made by a committee of technical experts from organizations on our coalition. These recommendations serve only as guidelines for training programs.

RELATED ACADEMIC SKILLS

COMMUNICATION SKILLS

Assumption of basic reading skills.
Assumption of basic keyboard skills

C1 Compose and edit using correct punctuation
- C1.1 sentences
- C1.2 paragraphs
- C1.3 written drafts
- C1.4 oral drafts

C2 Compose and edit sentences or paragraphs for completeness/irregular expressions/modifiers/cause and effect relationships/ paragraph coherence/paragraph transitions

C3 Compose and edit reports, essays, information requests, persuasive text, proofs and revisions, summaries, social communications and business letters

C4 Compose and edit general forms or documents

C5 Compose and edit audio-visual aids

C6 Compose and edit notes

C7 Spelling and vocabulary
- C7.1 compose and edit sentences using correct spelling
- C7.2 identify information and written abbreviations
- C7.3 apply and use definitions

C8 Use text resource table of contents, resource glossaries, resource indexes

C9 Collect, organize, and research oral and written information

C10 Use reference books, manufacturers' manuals, library resources, and trade publications

C11 Read and comprehend written information
- C11.1 the main idea
- C11.2 the purpose
- C11.3 the conclusion

C15 Evaluate written facts and opinions

C16 Identify written information when reading

C17 Adapt strategic listening by adhering to directions, tasks, nonverbal and verbal cues

C18 Apply informal oral communications from employee to supervisor, supervisor to employee, peer to peer, with customers and others

C19 Adapt communication techniques to cultural differences

C20 Use library resource card catalogs

C21 Use library resource guides

C22 Collect and organize information to adapt to strategy writing for oral and written presentations

C23 Comprehend information when reading

C24 Adapt listening skills and attend verbal and nonverbal cues

C25 Evaluate information when listening for clarity and appropriateness

C26 Present speech for formal and/or informal information request

MATH SKILLS

M1 Basic arithmetic operations - compute addition, subtraction, multiplication, division (mentally and/or calculator) for the following categories: whole numbers, decimals, fractions, and mixed numbers

M2 Basic arithmetic operations - conversions: units, square units, identify English measures length/volume/weight, convert units metric/English, convert units and time

M3 Basic arithmetic operations - probability and statistics: interpret charts/tables/graphs

M4 Geometry - reasoning and logic:
- M4.1 understand definitions, conditions
- M4.2 formulate and verifies conclusions
- M4.3 solve problems, generate conclusions, deductive resoning.
- M4.4 calculate and evaluate reasoning- invalidate arguments

M5 Geometry - calculate and evaluate geometric figures:

M5.1 perimeter
- M5.2 circumference
- M5.3 area
- M5.4 surface
- M5.5 volume
- M5.6 congruent triangles

M6 Geometry - construct geometric figures: lines, angles, congruent angles, congruent segments, angle bisectors, parallel/perpendicular, geometric figures, and three dimensional figures

M7 Geometry - measurement:
- M7.1 measure direct - distance
- M7.2 calculate and evaluate measurement precisely,
- M7.3 formulate and verify angles - acute/obtuse/right
- M7.4 measure direct angles
- M7.5 estimate and round
- M7.6 classify triangles by sides and angles

M8 Geometry - identify geometric figures and symbols:
- M8.1 interpret symbols
- M8.2 identify lines
- M8.3 identify lines - vertical/horizontal
- M8.4 identify lines-parallel/perpendicular
- M8.5 identify lines - ray/segment
- M8.6 distinguish angles/circle/arcs
- M8.7 identify geometric figures circles/angles/arcs/polygons
- M8.8 identify geometric figures
- M8.9 understand geometric figures: visual perception

M9 Algebra - graphing: calculate and evaluate Cartesian midpoints

M10 Algebra - graphing: solve problems - coordinate geometry and conic sections

M11 Algebra - graphing: solve problems - coordinate geometry and distance formula

M12 Trigonometry - use calculator to compute trigonometric functions (e.g., cosines/sines/tangents)

M13 Convert decimals/fractions/ratios/percentages

SCIENCE SKILLS

S1 Apply and use maps/charts/tables/graphs
S2 Convert measurement units
S3 Measure direct distance and/or length
S4 Measure direct angles
S5 Describe and explain color in general, related to blindness, cones, pigmentation, rainbows, rods, and spectra
S6 Describe and explain lenses including concave, convex, and focal length
S7 Describe and explain light including angle of incidence and reflection, critical angle -- fiber optics, diffraction, electromagnetic radiation, electromagnetic spectrum, fluorescent, incandescent, lasers, opaque, photoelectric, photons, polarization, refraction, speed, translucent and transparent, and ultraviolet
S8 Identify measurement units
S9 Measure mass and weight
S10 Measure volume including liquids and solids
S11 Use computers to process information, for mathematical applications and problem solving

EMPLOYABILITY SKILLS

These are defined as skills and behaviors that are known, valued, and practiced in the workplace.

RESOURCES:

- Identify, organize, plan, and allocate resources
- Select drawing relevant activity, allocate time, keep records and follow schedule
- Use company resources responsibly (e.g., supplies, equipment)

INTERPERSONAL:

- Work with others
- Participate as member of team (e.g., following instructions, providing feedback, cooperating with established team goals)
- Serve Clients/Customers - work to satisfy customers' expectations (internal and external customers)
- Maintain professional respect for co-workers and customers without prejudice
- Understand how the structure of the organization works and work effectively within it
- Communicate effectively with work related personnel
- Provide job-related instruction to others

INFORMATION:

- Acquire and use information
- Acquire and evaluate job-related documents
- Organize and maintain files
- Interpret and communicate job-related information
- Use computers to process information in the work environment

SYSTEMS:

- Understand complex terminology
- Is familiar with inter-relationships used in the profession
- Understand the technical aspects of everyday life on the job and the tools that relate to the profession
- Suggest modifications to existing processes and develop new or alternative methodologies to improve performance

TECHNOLOGY:

- Work with a variety of technologies
- Apply current and appropriate technology to specific tasks

THINKING SKILLS

- Think creatively
- Make intelligent decisions
- Solve problems
- Visualize, organize and process symbols, pictures, graphs, objects, and other information
- Use efficient learning techniques to acquire and apply new knowledge and skills
- Practice deductive and inductive reasoning skills

PERSONAL QUALITIES

- Practice individual responsibility
- Have good self-esteem, believe in own self-worth, and maintain a positive view of self
- Relate well to others
- Set personal goals, monitor progress, and exhibit self-control
- Possess integrity
- Maintain a professional image
- Demonstrate dependability
- Demonstrate a good work ethic
- Demonstrate willingness to learn
- Provide constructive praise or criticism
- Demonstrate flexibility
- Work safely
- Balance work, family, and personal life

GENERAL KNOWLEDGE OF THE INDUSTRY

- Know the scope of the industry and how parts interrelate
- Understand the economics pertinent to the department (e.g., supply costs, productivity, business financial decisions)
- Read, analyze and interpret examples of industry reports and specifications and standards

TOOLS and EQUIPMENT for CADD TRAINING

Recommendation

CADD software is designed to run on a wide range of hardware platforms such as personal computers, engineering workstations, mini-computers or mainframes. Most CADD software can be run on a variety of hardware platforms, each of which has advantages and disadvantages in terms of price and performance. Due to the rapidly evolving computer technology and related software capabilities, specific component designations must be made on an individual basis. The key factor to success is to match needs with abilities, performance, and cost. Considering these factors, the following guidelines are provided.

CADD system hardware selection will have to consider the following components in the selection process:

- CPU (e.g. processor, RAM)
- display system (e.g. monitor, graphic cards)
- input peripherals (e.g. mouse, graphics tablet)
- output peripherals (e.g. plotter, laser printer)
- mass storage devices (e.g. floppy disk, hard disk)
- back-up devices (e.g. tape drive, WORM drive)
- accessories (e.g. CD-ROM drive, UPS, modem)
- network (e.g. data)
- training accessories (e.g. video network, projection devices)

The recommended process for selecting a CADD system is:

1. Review the Core CADD Skills document and determine the CADD skills to be learned.
2. Investigate/choose the CADD software that will best accomplish the learning of these skills selected.
3. Select appropriate computer hardware for the CADD software selected. Thus, the hardware should always be selected LAST.

THE IDEAL TRAINING ENVIRONMENT HAS ONE LEARNER PER WORK STATION.

HOURS of INSTRUCTION

Recommendation

The following is an estimate of the number of hours required to teach the different segments of each core CADD technical skill area, excluding the related academic skills. Portions of these areas can be taught concurrently. Hours include lab and classroom hours.

FUNDAMENTAL DRAFTING SKILLS	80 to 130 hours
FUNDAMENTAL COMPUTER SKILLS	10 to 30 hours
BASIC CADD SKILLS	80 to 130 hours
ADVANCED CADD SKILLS	120 to 220 hours

QUALIFICATIONS of a CADD INSTRUCTOR

Recommendation

These guidelines are informational only. It is understood that some instructors may be qualified with less than minimum recommended criteria; and some instructors may be unqualified regardless of education or experience.

GUIDELINES FOR QUALIFICATIONS OF A CADD INSTRUCTOR

- Must demonstrate a mastery of content as outlined by the CADD skill standards document. Mastery can be demonstrated by passing the national voluntary CADD test
- Demonstrate the ability to teach using curriculum and lesson planning guide
- Be able to update experience through internship, software training, etc.
- A related degree or equivalent work experience according to chart below

No Degree -	8 yrs of related work experience with 2 years being recent CADD experience
AS Degree -	4 years of related work experience with 2 years being recent CADD experience
BS/MS/PhD -	2 years of related work experience with 2 years being recent CADD experience